Appendices

Appendix A: Matlab Codes

Appendix A.1: Case 1: Null Discriminant (3 real eigenvalues: 2 of them are repeated)

```
clc;
hold on
for r=0.103340423 % Initial value of the inflation rate
   for d=0.001325775 % Initial value of the instantaneous rate of change of the inflation rate
   for q=-0.00167909 % Initial value of the instantaneous rate of change of the real interest rate
   for ro=0.060669713 % Initial value of the real interest rate
      c=0.12; betha=0.21; g=3.99; thetha=g/(1-c); h=0.15; epsilon=0.6; n=0; mhu=0.05; alpha=4*betha*(h+epsilon*thetha)/(thetha*(1-
h*betha).^2);psi=1.1;
      delta=psi/(1-c);yop=1;pie=((thetha*mhu-n*(h+epsilon*thetha))/thetha);
      k2=((2*betha)*(r-pie)+(1-h*betha)*d)/((h+epsilon*thetha)*(1+h*betha));
      k3=(-d*(1-h*betha).^2)/((2*betha)*(h+epsilon*thetha)*(1+h*betha));
      k1=q+(n/thetha)-k3-k2*(1-h*betha).^2/((2*betha)*(1+h*betha));
      k4=ro+k1/betha+(1-h*betha).^2/(2*betha).^2*(k2*((1-h*betha)/(1+h*betha)+1)+k3*(2*betha)/(1-h*betha));
      t=0:90;
% Inflation rate
x=(h+epsilon*thetha)*(1+h*betha)*(k2*(t/(1-h*betha)+1/(2*betha))+k3/(1-h*betha)).*exp(((2*betha)/(h*betha-1))*t)+pie;
% Rate of change of the inflation rate
y=-((2*betha)*(h+epsilon*thetha)*(1+h*betha))/((1-h*betha).^2)*(k2*t+k3).*exp(((2*betha)/(h*betha-1))*t);
% Rate of change of the real rate of interest
z=k1.*exp((-betha)*t)+(k2*((1-h*betha).^2/((2*betha)*(1+h*betha))+t)+k3).*exp(((2*betha)/(h*betha-1))*t)-(n/thetha);
% Real rate of interest
w=k4-(k1/betha).*exp((-betha)*t)-(n/thetha)*t-(1-h*betha)/(2*betha)*(k2*((1-h*betha).^2/((2*betha)*(1+h*betha))+(1-betha*(h-
2*t))/(2*betha))+k3).*exp(((2*betha)/(h*betha-1))*t);
% Real GDP (In levels)
u=exp(delta-thetha*(w));
% Expected rate of inflation
a=x-alpha*(log(u)-yop);
figure (1)
grid on
subplot (3,2,1);
plot (t, x,'linewidth',3)
title ('Inflation rate')
xlabel ('t'), ylabel ('\pi','rotation',360);
hold on
grid on
subplot (3,2,2);
plot (t, y,'linewidth',3)
title ('Instantaneous rate of change of the inflation rate')
xlabel ('t'), ylabel ('\pi\prime','rotation',360);
hold on
grid on
subplot (3,2,3);
plot (t, z,'linewidth',3)
title ('Instantaneous rate of change of the real interest rate')
xlabel ('t'), ylabel('r\prime','rotation',360);
hold on
grid on
subplot (3,2,4);
plot (t, w,'linewidth',3)
title ('Real interest rate')
xlabel ('t'), ylabel('r','rotation',360);
hold on
grid on
subplot (3,2,5);
plot (t, u,'linewidth',3)
title ('Real GDP (In levels)')
xlabel ('t'), ylabel ('Y','rotation',360)
hold on
grid on
subplot (3,2,6)
plot (t, a,'linewidth',3)
title ('Expected inflation rate')
xlabel ('t'), ylabel ('{\pi^{e}}','rotation',360)
grid on
hold on
figure (2)
f = @(t,x)[x(2);((-alpha*betha*thetha)/(h+epsilon*thetha))*x(1)+((alpha*thetha*(h*betha-
1))/(h+epsilon*thetha))*x(2)+(alpha*betha*(mhu*thetha-n*(h+epsilon*thetha)))/(h+epsilon*thetha);((betha)/(h+epsilon*thetha))*x(1)+((1-
h*betha)/(h+epsilon*thetha))*x(2)-betha*x(3)-(betha*mhu)/(h+epsilon*thetha)];
            [t,x]=ode45(f,0:0.25:90,[r; d; q]);
x1= x (:,1);
x2= x (:,2);
```

```
x3= x (:,3);
grid on
plot3 (x1, x2, x3,'-','Color','b','linewidth',3,'MarkerSize',6,'MarkerFaceColor','#D9FFFF'); grid on;
view (55,25)
hold on;
plot3 (r, d, q,'ko','linewidth',1,'MarkerFaceColor','k','MarkerSize',6); hold on;
plot3 (x1,0.002+0*x2, x3,'m:','linewidth',3,'MarkerFaceColor','r','MarkerSize',6),
plot3 (0.04+0*x1, x2, x3,'g:','linewidth',3,'MarkerFaceColor','r','MarkerSize',6),
plot3 (x1, x2, -0.002+0*x3,'r:','linewidth',3,'MarkerFaceColor','r','MarkerSize',6),
hold on
xlabel ('\pi');
ylabel ('\pi\prime');
zlabel ('r\prime','rotation',360);
title ('Phase portrait: IS-LM-AS model');
axis ([0.04 0.11 -0.009 0.002 -0.002 0.002]);
hold on;
figure (3)
grid on
subplot (3,3, [1,3])
plot (x1, x3,'m:','linewidth',3,'MarkerFaceColor','r','MarkerSize',6)
% title ('r\prime')
Xlabel ('r\prime'), ylabel ('\pi','rotation',360);
grid on
subplot (3,3,[4,6])
plot (x2, x3,'g:','linewidth',3,'MarkerFaceColor','r','MarkerSize',6),
% title ('Time-paths of the rate of change of the inflation rate')
Xlabel ('\pi\prime'), ylabel ('r\prime','rotation',360);
grid on
subplot (3,3, [7,9])
hold on
plot (x1, x2,'r:','linewidth',3,'MarkerFaceColor','r','MarkerSize',6),
% title ('Time-paths of the rate of change of the interest rate')
xlabel ('\pi'), ylabel('\pi\prime','rotation',360);
grid on
hold on
% Comprobation
figure (4)
grid on
subplot (3,3, [1,3])
plot (t, x1)
title ('Time-paths of the inflation rate')
xlabel ('t'), ylabel ('\pi','rotation',360);
grid on
subplot (3,3, [4,6])
plot (t, x2)
title ('Time-paths of the rate of change of the inflation rate')
xlabel ('t'), ylabel ('\pi\prime','rotation',360);
grid on
subplot (3,3, [7,9])
hold on
plot (t, x3)
title ('Time-paths of the rate of change of the interest rate')
xlabel ('t'), ylabel ('r\prime','rotation',360);
grid on
hold on
   end
   end
   end
end
hold on
hold off
```

Appendix A.2: Case 2: Positive Discriminant (3 real and different eigenvalues)

```
clc;
hold on
for r=0.199873255 % Initial value of the inflation rate
   for d=-0.044686969 % Initial value of the instantaneous rate of change of the inflation rate
   for q=0.027 % Initial value of the instantaneous rate of change of the real interest rate
   for ro=0.0034487 % Initial value of the real interest rate
       c=0.12; betha=0.25; g=3.99; thetha=g/(1-c); h=0.01; epsilon=0.45; n=0; mhu=0.04; alpha=0.7;psi=1.1;
       delta=psi/(1-c);yop=1;
       pie=((thetha*mhu-n*(h+epsilon*thetha))/thetha);
       Discr=-alpha*thetha*(4*betha*(h+epsilon*thetha)-alpha*thetha*(1-h*betha).^2);
       lambda1=-betha;
       lambda2=(-alpha*thetha*(1-h*betha)+Discr^0.5)/(2*(h+epsilon*thetha));
       lambda3=(-alpha*thetha*(1-h*betha)-Discr^0.5)/(2*(h+epsilon*thetha));
       k2=((r-pie)*((Discr^0.5+alpha*thetha*(1+h*betha))/(h+epsilon*thetha))+2*d*(1-h*lambda2))/((1-
h*lambda3)*(Discr^0.5+alpha*thetha*(1+h*betha))+(1-h*lambda2)*(Discr^0.5-alpha*thetha*(1+h*betha)));
       k3=(k2*(Discr^0.5-alpha*thetha*(1+h*betha))-2*d)/((Discr^0.5+alpha*thetha*(1+h*betha)));
       k1=q+(n/thetha)-k3-k2;
       k4=ro-k1/lambda1-k2/lambda2-k3/lambda3;
       t=0:140;
% Inflation rate
x=k2*(h+epsilon*thetha) *(1-h*lambda3).*exp(lambda2*t)+k3*(h+epsilon*thetha)*(1-h*lambda2).*exp(lambda3*t)+pie;
% Instantaneous rate of change of the inflation rate
y=k2.*exp(lambda2*t)*(Discr^0.5-alpha*thetha*(1+h*betha))/2-k3.*exp(lambda3*t)*(Discr^0.5+alpha*thetha*(1+h*betha))/2;
% Instantaneous rate of change of the real rate of interest
z=k1.*exp(lambda1*t)+k2.*exp(lambda2*t)+k3.*exp(lambda3*t)-(n/thetha);
% Real rate of interest
w=k4-(k1/betha).*exp(lambda1*t)-(n/thetha)*t+(k2/lambda2).*exp(lambda2*t)+(k3/lambda3).*exp(lambda3*t);
% Real GDP (In levels)
u=exp(delta-thetha*(w));
% Expected rate of inflation
a=x-alpha*(log(u)-yop);
figure (1)
grid on
subplot (3,2,1);
plot (t, x,'linewidth',3)
title ('Inflation rate')
xlabel ('t'), ylabel ('\pi','rotation',360);
hold on
grid on
subplot (3,2,2);
plot (t, y,'linewidth',3)
title ('Instantaneous rate of change of the inflation rate')
xlabel ('t'), ylabel ('\pi\prime','rotation',360);
hold on
grid on
subplot (3,2,3);
plot (t, z,'linewidth',3)
title ('Instantaneous rate of change of the real interest rate')
xlabel ('t'), ylabel ('r\prime','rotation',360);
hold on
grid on
subplot (3,2,4);
plot (t, w,'linewidth',3)
title ('Real interest rate')
xlabel ('t'), ylabel('r','rotation',360);
hold on
grid on
subplot (3,2,5);
plot (t, u,'linewidth',3)
title ('Real GDP (In levels)')
xlabel ('t'), ylabel ('Y','rotation',360)
hold on
grid on
subplot (3,2,6)
plot (t, a,'linewidth',3)
title ('Expected inflation rate')
xlabel ('t'), ylabel ('{\pi^{e}}','rotation',360)
grid on
hold on
figure (2)
f = @(t,x)[x(2);((-alpha*betha*thetha)/(h+epsilon*thetha))*x(1)+((alpha*thetha*(h*betha-
1))/(h+epsilon*thetha))*x(2)+(alpha*betha*(mhu*thetha-n*(h+epsilon*thetha)))/(h+epsilon*thetha);((betha)/(h+epsilon*thetha))*x(1)+((1-
h*betha)/(h+epsilon*thetha))*x(2)-betha*x(3)-(betha*mhu)/(h+epsilon*thetha)];
            [t,x]=ode45(f,0:140,[r; d; q]);
x1=x(:,1);
x2=x(:,2);
x3=x(:,3);
```

```
grid on
plot3 (x1, x2, x3,'-','Color','b','linewidth',3,'MarkerSize',6,'MarkerFaceColor','#D9FFFF'); grid on;
view (55,25)
hold on;
plot3 (r, d, q,'ko','linewidth',1,'MarkerFaceColor','k','MarkerSize',6); hold on;
plot3 (x1,0*x2+0.005, x3,'m:','linewidth',3,'MarkerFaceColor','r','MarkerSize',6),
plot3 (0.02+0*x1, x2, x3,'g:','linewidth',3,'MarkerFaceColor','r','MarkerSize',6),
plot3 (x1, x2, -0.02+0*x3,'r:','linewidth',3,'MarkerFaceColor','r','MarkerSize',6),
hold on
xlabel ('\pi');
ylabel ('\pi\prime');
zlabel ('r\prime','rotation',360);
title ('Phase portrait: IS-LM-AS Model');
axis tight % ([0.02 0.2 -0.015 0.005 -0.02 0.05]);
hold on;
figure (3)
grid on
subplot (3,3, [1,3])
plot (x1, x3,'m:','linewidth',3,'MarkerFaceColor','r','MarkerSize',6)
% title ('r\prime')
xlabel('r\prime'), ylabel('\pi','rotation',360);
grid on
subplot (3,3, [4,6])
plot (x2, x3,'g:','linewidth',3,'MarkerFaceColor','r','MarkerSize',6),
% title ('Time-paths of the rate of change of the inflation rate')
xlabel ('\pi\prime'), ylabel('r\prime','rotation',360);
grid on
subplot (3,3, [7,9])
hold on
plot (x1, x2,'r:','linewidth',3,'MarkerFaceColor','r','MarkerSize',6),
% title ('Time-paths of the rate of change of the interest rate')
Xlabel ('\pi'), ylabel('\pi\prime','rotation',360);
grid on
hold on
% Comprobation
figure (4)
grid on
subplot (3,3, [1,3])
plot (t, x1)
title ('Time-paths of the inflation rate')
xlabel ('t'), ylabel ('\pi','rotation',360);
grid on
subplot (3,3, [4,6])
plot (t, x2)
title ('Time-paths of the rate of change of the inflation rate')
xlabel ('t'), ylabel ('\pi\prime','rotation',360);
grid on
subplot (3,3, [7,9])
hold on
plot (t, x3)
title ('Time-paths of the rate of change of the interest rate')
xlabel ('t'), ylabel ('r\prime','rotation',360);
grid on
hold on
   end
   end
   end
end
hold on
hold off
```

Appendix A.3: Case 3: Negative Discriminant (1 real eigenvalue and 2 complex conjugated eigenvalues)

```
clc;
hold on
for r=0.1 % Initial value of the inflation rate
   for d=-0.001705909 % Initial value of the instantaneous rate of change of the inflation rate
   for q=-1.1017053 % Initial value of the instantaneous rate of change of the real interest rate
   for ro=0.203121033 % Initial value of the real interest rate
      alpha=0.9; c=0.03; betha=9; g=0.288; thetha=g/(1-c); h=0.1; epsilon=0.01; n=0; mhu=0.05; psi=1;
       delta=psi/(1-c); yop=1;
       pie=((thetha*mhu-n*(h+epsilon*thetha))/thetha);
       gamma=-(alpha*thetha*(1-h*betha))/(2*(h+epsilon*thetha));
       sigma=(alpha*thetha*(4*betha*(h+epsilon*thetha)-alpha*thetha*(1-h*betha).^2))^0.5/(2*(h+epsilon*thetha));
       k2=(r-pie)/(h+epsilon*thetha);
       k3=(d-gamma*(r-pie))/((h+epsilon*thetha)*sigma);
       Phi=((betha*(betha+gamma) + (1-h*betha)*(gamma*(betha+gamma)+sigma^2))*k2-
sigma*h*betha^2*k3)/((betha+gamma)^2+sigma^2);
       omega= ((betha*(betha+ gamma) +(1-
h*betha)*(gamma*(betha+gamma)+sigma^2))*k3+sigma*h*betha^2*k2)/((betha+gamma)^2+sigma^2);
       k1=q+(n/thetha)-Phi;
       k4=ro+k1/betha+(omega*sigma-Phi*gamma)/(gamma^2+sigma^2);
       t=0:1:30;
       % Inflation rate
x=(h+epsilon*thetha)*(k2*cos(sigma*t)+k3*sin(sigma*t)).*exp(gamma*t)+pie;
% Rate of change of the inflation rate
y=(h+epsilon*thetha)*((sigma*k3+gamma*k2)*cos(sigma*t)-(sigma*k2-gamma*k3)*sin(sigma*t)).*exp(gamma*t);
% Rate of change of the real rate of interest
z=k1.*exp((-betha)*t)+(Phi*cos(sigma*t)+omega*sin(sigma*t)).*exp(gamma*t)-(n/thetha);
% Real rate of interest
w=k4-(k1/betha).*exp((-betha)*t)-(n/thetha)*t+(((Phi*gamma-
omega*sigma)*cos(sigma*t)+(Phi*sigma+omega*gamma)*sin(sigma*t))/(gamma^2+sigma^2)).*exp(gamma*t);
% Real GDP (In levels)
u=exp(delta-thetha*(w));
% Expected rate of inflation
a=x-alpha*(log(u)-yop);
figure (1)
grid on
subplot (3,2,1);
plot (t, x,'linewidth',3)
title ('Inflation rate')
xlabel ('t'), ylabel ('\pi','rotation',360);
hold on
grid on
subplot (3,2,2);
plot (t, y,'linewidth',3)
title ('Instantaneous rate of change of the inflation rate')
xlabel ('t'), ylabel ('\pi\prime','rotation',360);
hold on
grid on
subplot (3,2,3);
plot (t, z,'linewidth',3)
title ('Instantaneous rate of change of the real interest rate')
xlabel ('t'), ylabel ('r\prime','rotation',360);
hold on
grid on
subplot (3,2,4);
plot (t, w,'linewidth',3)
title ('Real interest rate')
xlabel ('t'), ylabel ('r','rotation',360);
hold on
grid on
subplot (3,2,5);
plot (t, u,'linewidth',3)
title ('Real GDP (In levels)')
xlabel ('t'), ylabel ('Y','rotation',360)
hold on
grid on
subplot (3,2,6)
plot (t, a,'linewidth',3)
title ('Expected inflation rate')
xlabel ('t'), ylabel ('{\pi^{e}}','rotation',360)
grid on
hold on
figure (2)
f = @(t,x)[x(2);((-alpha*betha*thetha)/(h+epsilon*thetha))*x(1)+((alpha*thetha*(h*betha-
1))/(h+epsilon*thetha))*x(2)+(alpha*betha*(mhu*thetha-n*(h+epsilon*thetha)))/(h+epsilon*thetha);((betha)/(h+epsilon*thetha))*x(1)+((1-
h*betha)/(h+epsilon*thetha))*x(2)-betha*x(3)-(betha*mhu)/(h+epsilon*thetha)];
```

```
            [t,x]=ode45(f,0:1:30,[r; d; q]);
x1=x(:,1);
x2=x(:,2);
x3=x(:,3);
grid on
plot3 (x1, x2, x3,'-','Color','b','linewidth',3,'MarkerSize',6,'MarkerFaceColor','#D9FFFF'); grid on;
view (55,25)
hold on;
% set (gcf, 'color', 'b');
% set (gca, 'color', 'k');
plot3 (r, d, q,'ko','linewidth',1,'MarkerFaceColor','k','MarkerSize',6); hold on;
plot3 (x1, 0.5+0*x2, x3,'m:','linewidth',3,'MarkerFaceColor','r','MarkerSize',6),
plot3 (0.12+0*x1, x2, x3,'g:','linewidth',3,'MarkerFaceColor','r','MarkerSize',6),
plot3 (x1, x2, -1.4+0*x3,'r:','linewidth',3,'MarkerFaceColor','r','MarkerSize',6),
hold on
xlabel ('\pi');
ylabel ('\pi\prime');
zlabel ('r\prime','rotation',360);
title ('Phase portrait: IS-LM-AS model');
axis ([0 0.12 -0.26 0.5 -1.4 0.5]);
hold on;
figure (3)
grid on
subplot (3,3, [1,3])
plot (x1, x3,'m:','linewidth',3,'MarkerFaceColor','r','MarkerSize',6)
% title ('r\prime')
xlabel ('r\prime'), ylabel ('\pi','rotation',360);
grid on
subplot (3,3, [4,6])
plot (x2, x3,'g:','linewidth',3,'MarkerFaceColor','r','MarkerSize',6)
% title ('Time-paths of the instantaneous rate of change of the inflation rate')
xlabel ('\pi\prime'), ylabel ('r\prime','rotation',360);
grid on
subplot (3,3, [7,9])
plot (x1, x2,'r:','linewidth',3,'MarkerFaceColor','r','MarkerSize',6),
% title ('Time-paths of the instantaneous rate of change of the interest rate')
xlabel ('\pi'), ylabel ('\pi\prime','rotation',360);
hold on
% Comprobation
figure (4)
grid on
subplot (3,3, [1,3])
plot (t, x1)
title ('Time-paths of the inflation rate')
xlabel ('t'), ylabel ('\pi','rotation',360);
grid on
subplot (3,3, [4,6])
plot (t, x2)
title ('Time-paths of the rate of change of the inflation rate')
xlabel ('t'), ylabel('\pi\prime','rotation',360);
grid on
subplot (3,3, [7,9])
hold on
plot (t, x3)
title ('Time-paths of the rate of change of the interest rate')
xlabel ('t'), ylabel ('r\prime','rotation',360);
grid on
hold on
   end
   end
   end
end
hold on
hold off
```

Appendix A.4: Degenerate Hopf Bifurcations

```
clc;
hold on
for r=0.1 % Initial value of the inflation rate
   for d=0.005245478 % Initial value of the instantaneous rate of change of the inflation rate
   for q=-1.107065273 % Initial value of the instantaneous rate of change of the real interest rate
   for ro=0.198743521 % Initial value of the real interest rate
      alpha=0.9; c=0.03; h=0.1; g=0.288; thetha=g/(1-c); betha=1/h; epsilon=0.01; n=0; mhu=0.05; psi=1;
       delta=psi/(1-c); yop=1;
       pie=((thetha*mhu-n*(h+epsilon*thetha))/thetha);
       gamma=-(alpha*thetha*(1-h*betha))/(2*(h+epsilon*thetha));
        Discr=-alpha*thetha*(4*betha*(h+epsilon*thetha)-alpha*thetha*(1-h*betha).^2);
       sigma=(-Discr)^0.5/(2*(h+epsilon*thetha));
       k2=(r-pie)/(h+epsilon*thetha);
       k3=(d-gamma*(r-pie))/((h+epsilon*thetha)*sigma);
       Phi=((betha*(betha+gamma)+(1-h*betha)*(gamma*(betha+gamma)+sigma^2))*k2-
sigma*h*betha^2*k3)/((betha+gamma)^2+sigma^2);
       omega=((betha*(betha+gamma)+(1-
h*betha)*(gamma*(betha+gamma)+sigma^2))*k3+sigma*h*betha^2*k2)/((betha+gamma)^2+sigma^2);
       k1=q+(n/thetha)-Phi;
       k4=ro+k1/betha+(omega*sigma-Phi*gamma)/(gamma^2+sigma^2);
       t=0:140;
       % Inflation rate
x=(h+epsilon*thetha)*(k2*cos(sigma*t)+k3*sin(sigma*t)).*exp(gamma*t)+pie;
% Instantaneous rate of change of the inflation rate
y=(h+epsilon*thetha)*((sigma*k3+gamma*k2)*cos(sigma*t)-(sigma*k2-gamma*k3)*sin(sigma*t)).*exp(gamma*t);
% Instantaneous rate of change of the real rate of interest
z=k1.*exp((-betha)*t)+(Phi*cos(sigma*t)+omega*sin(sigma*t)).*exp(gamma*t)-(n/thetha);
% Real rate of interest
w=k4-(k1/betha).*exp((-betha)*t)-(n/thetha)*t+(((Phi*gamma-
omega*sigma)*cos(sigma*t)+(Phi*sigma+omega*gamma)*sin(sigma*t))/(gamma^2+sigma^2)).*exp(gamma*t);
% Real GDP (In levels)
u=exp(delta-thetha*(w));
% Expected rate of inflation
a=x-alpha*(log(u)-yop);
figure (1)
grid on
subplot (3,2,1);
plot (t, x,'linewidth',3)
title ('Inflation rate')
xlabel ('t'), ylabel ('\pi','rotation',360);
hold on
grid on
subplot (3,2,2);
plot (t, y,'linewidth',3)
title ('Instantaneous rate of change of the inflation rate')
xlabel ('t'), ylabel ('\pi\prime','rotation',360);
hold on
grid on
subplot (3,2,3);
plot (t, z,'linewidth',3)
title ('Instantaneous rate of change of the real interest rate')
xlabel ('t'), ylabel ('r\prime','rotation',360);
hold on
grid on
subplot (3,2,4);
plot (t, w,'linewidth',3)
title ('Real interest rate')
xlabel ('t'), ylabel ('r','rotation',360);
hold on
grid on
subplot (3,2,5);
plot (t, u,'linewidth',3)
title ('Real GDP (In levels)')
xlabel ('t'), ylabel ('Y','rotation',360)
hold on
grid on
subplot (3,2,6)
plot (t, a,'linewidth',3)
title ('Expected inflation rate')
xlabel ('t'), ylabel('{\pi^{e}}','rotation',360)
grid on
hold on
figure (2)
f = @(t,x)[x(2);((-alpha*betha*thetha)/(h+epsilon*thetha))*x(1)+((alpha*thetha*(h*betha-
1))/(h+epsilon*thetha))*x(2)+(alpha*betha*(mhu*thetha-n*(h+epsilon*thetha)))/(h+epsilon*thetha);((betha)/(h+epsilon*thetha))*x(1)+((1-
h*betha)/(h+epsilon*thetha))*x(2)-betha*x(3)-(betha*mhu)/(h+epsilon*thetha)];
            [t,x]=ode45(f,0:140,[r; d; q]);
```

```
x1=x(:,1);
x2=x(:,2);
x3=x(:,3);
grid on
plot3 (x1, x2, x3,'-','Color','b','linewidth',3,'MarkerSize',6,'MarkerFaceColor','#D9FFFF'); grid on;
view (55,25)
hold on;
% set (gcf, 'color', 'b');
% set (gca, 'color', 'k');
plot3(r, d, q,'ko','linewidth',1,'MarkerFaceColor','k','MarkerSize',6); hold on;
plot3(pie,0,0,'ko','linewidth',1,'MarkerFaceColor','k','MarkerSize',6); hold on;
plot3 (x1,0.3+0*x2, x3,'m:','linewidth',3,'MarkerFaceColor','r','MarkerSize',6),
plot3 (-0.01+0*x1, x2, x3,'g:','linewidth',3,'MarkerFaceColor','r','MarkerSize',6),
plot3 (x1, x2, -1.4+0*x3,'r:','linewidth',3,'MarkerFaceColor','r','MarkerSize',6),
hold on
xlabel ('\pi');
ylabel ('\pi\prime');
zlabel ('r\prime','rotation',360);
title ('Phase portrait: IS-LM-AS model');
axis ([-0.01 0.12 -0.3 0.3 -1.4 0.6]);
hold on;
figure (3)
grid on
subplot (3,3, [1,3])
plot (x1, x3,'m:','linewidth',3,'MarkerFaceColor','r','MarkerSize',6)
% title ('r\prime')
xlabel ('r\prime'), ylabel('\pi','rotation',360);
grid on
subplot (3,3, [4,6])
plot (x2, x3,'g:','linewidth',3,'MarkerFaceColor','r','MarkerSize',6)
% title ('Time-paths of the rate of change of inflation rate')
xlabel ('\pi\prime'), ylabel('r\prime','rotation',360);
grid on
subplot (3, 3, [7,9])
plot (x1, x2,'r:','linewidth',3,'MarkerFaceColor','r','MarkerSize',6),
% title ('Time-paths of the rate of change of the interest rate')
xlabel ('\pi'), ylabel ('\pi\prime','rotation',360);
hold on
% Comprobation
figure (4)
grid on
subplot (3, 3, [1,3])
plot (t, x1)
title ('Time-paths of the inflation rate')
xlabel ('t'), ylabel ('\pi','rotation',360);
grid on
subplot (3, 3, [4,6])
plot (t, x2)
title ('Time-paths of the rate of change of the inflation rate')
xlabel ('t'), ylabel ('\pi\prime','rotation',360);
grid on
subplot (3, 3, [7,9])
hold on
plot (t, x3)
title ('Time-paths of the rate of change of the interest rate')
xlabel ('t'), ylabel ('r\prime','rotation',360);
grid on
hold on
   end
   end
   end
end
hold on
hold off
```